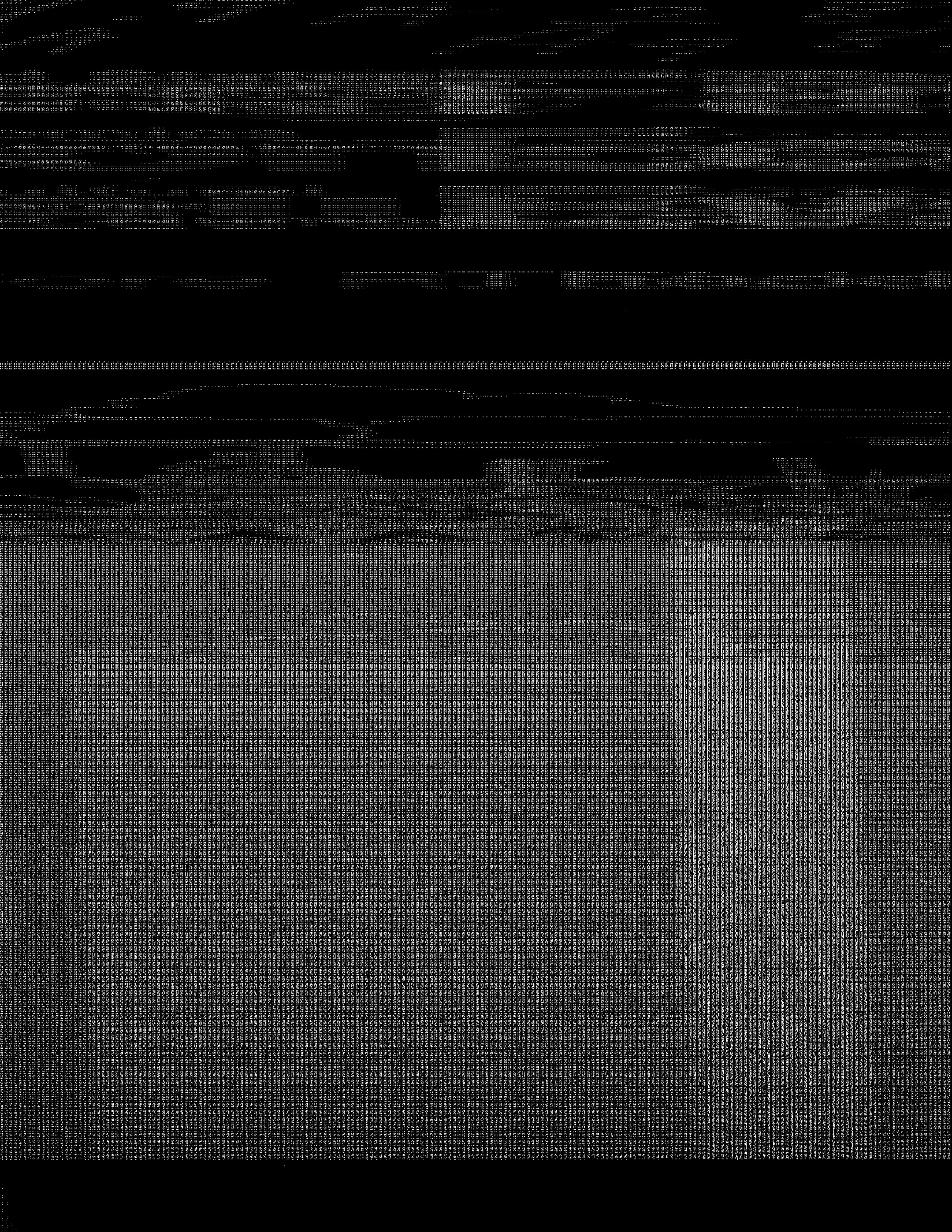

FARM PESTICIDE ECONOMIC EVALUATION, 1981. Theodore R. Eichers, National Economics Division, Economics and Statistics Service, U.S. Department of Agriculture. Agricultural Economic Report No. 464.

ABSTRACT

Insecticide purchases for 1981 will increase 10 to 15 percent over the last 2 years, when use was down because of light insect infestations. Herbicide use will rise about 5 percent. Supplies of nearly all pesticides should be ample because of unusually large carryover stocks. Prices may be up about 10 percent because of rising production and distribution costs. Rebuttable Presumption Against Registration (RPAR) proposed decisions were published by EPA for four pesticides in 1980: diallate, lindane, EDB, and strychnine.

Keywords: Pesticide production, Pesticide supply, Pesticide demand, Pesticide prices, Pesticide outlook, Pesticide regulations, Alternative pest controls.

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Washington, D.C. March 1981

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SUMMARY

Insecticide purchases for 1981 are likely to be 10 to 15 percent over the last 2 years, while herbicide use will rise 5 percent. Pesticide supplies should again be adequate for the 1981 season, with herbicide supplies up 8 percent, fungicide supplies unchanged, and insecticide supplies off 3 percent.

While insecticide demand is up, supplies should still be sufficient because manufacturers ended the 1980 season with more than a third of the year's production in their warehouses. There were light insect infestations in 1979 and 1980.

Pesticide prices are likely to average about 10 percent higher for both herbicides and insecticides. Pesticide prices last year were 5 to 15 percent higher than a year earlier. However, atrazine continued a 4-year decline with a 6-percent price drop, while the price of 2,4-D jumped 50 percent.

Pesticide prices rose at about half the rate for other farm inputs during the seventies, 70 percent compared to 146 percent. Pesticides are a small share of total farm production costs, about 3 percent. Pesticide costs in 1980 ranged from 2.3 percent of total production costs (exclusive of land) for wheat to 14.7 percent for peanuts.

The pesticide market will continue to grow in the eighties, particularly for herbicides. But, the growth rate will be much less rapid than in the seventies and sixties. Growth in export markets will be more rapid than in the domestic markets, and growth in developing nations will be more rapid than in developed nations.

Regulations continue to play an important role in farmers' pesticide decisionmaking. Rebuttable Presumption Against Registration (RPAR) proposed regulatory actions were issued in 1980 for diallate, lindane, ethylene dibromide (EDB), and strychnine. The Environmental Protection Agency initiated the registration standards program in 1980.

Farm Pesticide Economic Evaluation, 1981

Theodore R. Eichers
Agricultural Economist

INTRODUCTION

Farmers will buy more herbicides and insecticides in 1981 than in the past 2 years, and they will pay about 10 percent more than last year, according to this report which provides current market and 1981 crop season outlook information on farm pest control. Emphasis is on pesticide supplies and demand, availability and use of pesticide alternatives, and effects of Government regulation.

The pesticide supply data are based on information obtained from 17 basic pesticide manufacturers, accounting for about two-thirds of the farm pesticides produced, and from regional pesticide distributors. The demand discussion is based on U.S. Department of Agriculture crop planting forecasts and on farm survey data on acres treated and application rates. Information on pesticide regulations and alternative controls is based on data from the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and other sources.

PESTICIDE SUPPLY AND DEMAND

Adequate supplies, increasing purchases, and higher prices highlight the 1981 pesticide situation.

Supplies

Pesticide supplies should be adequate for the 1981 season. Basic manufacturers' supplies of pesticides should be up 4 percent over last season, with herbicide supplies up 8 percent, insecticide supplies down 3 percent, and fungicide supplies the same as last year (table 1).

Beginning inventories for the 1981 crop year, 48 percent greater than levels at the start of the 1980 season, amount to over a third of last year's production, about twice the desired level (table 1). Manufacturers are cutting insecticide output to just over 60 percent of available capacity (table 2). Although herbicide inventory carryovers to 1981 also were substantial, production facilities are scheduled to operate at 85-percent capacity.

Supplies of all pesticide materials were ample last year with more than adequate supplies in many areas, especially the Cotton Belt. The synthetic pyrethroid insecticides, registered on an expedited basis since 1977 for controlling cotton bollworms and budworms, continue to make inroads into the markets for traditional insecticides such as toxaphene, methyl parathion, and EPN.

Table 1--Pesticide production and inventories for basic pesticide producers

Item	Fungicides	Herbicides	Insecticides	All pesticides
	Percent			
Projected 1981 production (percentage of 1980)	99	105	96	102
Inventory carryover:				
For 1981 (percentage of production) 1/	31	33	36	34
Change from 1980	41	106	9	48
Projected 1981 net supply (percentage of 1980)	100	108	97	104

1/ Inventories at the start of the season are based on production in 1980.

Source: Based on a survey of 17 basic pesticide producers conducted in September-October 1980.

Table 2--Pesticide production capacity utilization and capacity expansion

Pesticide	Production as a percentage of capacity		Capacity expansion, percentage change	
	1980	Projected 1981	1979-80	1980-81
	Percent			
Fungicides	82	82	3	0
Herbicides	81	85	2	3
Insecticides	64	61	1	0
All pesticides	77	76	2	2

Source: Based on a survey of 17 basic pesticide producers conducted in September-October 1980.

Demand

Insecticide purchases for 1981 are likely to be up 10 to 15 percent over those of the last 2 years. Insect infestations were light in 1979 and 1980. Herbicide use should be up about 5 percent.

Farm insecticide purchases in 1980 were down for the second consecutive year, because of low insect populations and poor crop conditions caused by drought in much of the South. Purchases were also affected by some corn growers in the Corn Belt who cut back on insurance use of soil insecticides. However, certain insects such as crickets and grasshoppers were more of a problem than normal (10).1/

Herbicide sales were up slightly in 1980 as farmers, spurred by increasing fuel costs, continued to replace mechanical cultivation with chemicals. Currently, 85 to 90 percent of the corn, cotton, soybean, peanut, and rice acreage is treated with herbicides at an average rate of about 2 pounds of active ingredient (a.i.) per acre. Total crop acreages are not expected to differ much from last year for the four major crops which account for 85 percent of the herbicide use and 70 percent of the insecticide use (table 3).

Although anticipated pesticide demand for 1981 is up more than expected production, carryover from last year's supply appears ample to meet anticipated farm needs.

Table 3--Crops' share of total pesticide use in 1980 and projected 1981 crop acreage change

Crop	Share of all pesticides used (active ingredients)		Projected crop acreage, 1981 change from 1980
	Herbicides	Insecticides	
	---Percent---		Percent
Corn	53	20	2
Cotton	5	40	-1
Soybeans	21	5	-2
Wheat	6	5	8
Combined	85	70	3

Source: (12, 24).

1/ Underscored numerals in parentheses refer to items in References section.

The quantity (pounds a.i.) of pesticides purchased by farmers during the 1966-80 period increased 140 percent, while expenditures increased 540 percent (table 4). Inflation accounted for much of the increase; but, a major share of the price rise reflects the introduction and expanded use of more selective pesticides which are more costly to develop and produce. Farmers' expenditures for pesticides increased much more during the seventies than the use of other production inputs in constant and current dollar terms (table 5).

Use of pesticides has grown rapidly, mainly because their prices have increased only half as much as other inputs and because farmers need to protect the growing investment required in producing a crop. Most of the pesticide growth was in herbicide use as farmers continued to replace mechanical cultivation with chemical weed control. The increased use of multichemical products, tank mixes, and multiple sequential applications to obtain season-long weed control and the control of problem weeds also contributed to the rapid herbicide growth rate.

Herbicides account for two-thirds of all pesticides (a.i.) used by farmers, about twice the share in 1966 (table 6). The average annual herbicide use rate on major crops increased from 1.4 pounds a.i. per acre to 2.0 pounds per acre in the 1971-76 period (12). The insecticide use share dropped by half from 1966 to 1980. The fungicide share also dropped.

Total insecticide use declined in the past 2 years for several reasons: below normal levels of insect infestation; greater use of Integrated Pest Management (IPM) programs (see later section) and alternative controls; and greater use of synthetic pyrethroids, applied at much lower rates and less frequently than traditional chemicals.

Prices

Farm herbicide and insecticide prices for 1981 are expected to average about 10 percent more than last year. Manufacturers quote price increases of 8 to 12 percent to distributors. These increases are likely to be passed on to the grower as distributor margins are reported to be minimal.

Farm pesticide prices last season were generally 5 to 15 percent higher than the year before (table 7). The price of atrazine, however, continued a 4-year decline, while the price of 2,4-D jumped 51 percent. Because of light cotton insect infestations, synthetic pyrethroid prices were reportedly cut 20 to 30 percent by some dealers.

Pesticide prices during the seventies increased at only about half the rate of farm production items in general (table 8). However, with heavy reliance on petroleum feedstocks, a reduction in market growth or even a decline for some types of materials, greater restrictions on use, and increasing adoption of alternative controls, pesticide prices are likely now to keep pace with the general inflation rate.

Table 4--Quantity and value of pesticides used, 1966-80

Year	Quantity used (a.i.)	Expenditures	Value per pound
	Mil. pounds	Mil. dollars	Dollars
1966	353	561	1.59
1971	494	1,002	2.03
1976	660	1,934	2.93
1980	846	3,600	4.25
		Percent	
Percentage change 1966-80	140	540	167

Sources: (12, 21, 27).

Table 5--Indexes of farmers' pesticide expenditures and total farm expenditures

Year	Current dollars		Constant dollars	
	Pesticide expenditures	All farm expenditures	Pesticide expenditures	All farm expenditures
	1970 = 100			
1970	100	100	100	100
1971	102	107	100	101
1972	107	118	102	106
1973	125	148	116	115
1974	155	164	128	112
1975	220	172	135	107
1976	197	189	111	110
1977	205	201	128	112
1978	248	229	165	117
1979	312	270	204	121
1980	367	299	212	116

Sources: (20, 21).

Table 6--Share of types of pesticides (a.i.) used by farmers

Year	Herbicides	Insecticides	Fungicides	Other	Total
			Percent		
1966	32	42	9	17	100
1971	47	34	9	10	100
1976	60	25	7	8	100
1980	67	20	6	7	100

Source: (12, 27).

Table 7--Average prices paid by farmers for selected pesticides

Product 1/	Price per pound (a.i.) 2/			Price change	
	1978	1979	1980	1978-79	1979-80
	-----Dollars-----			---Percent---	
Insecticides:					
Carbaryl	2.40	2.56	2.86	7	12
Malathion	2.76	2.76	3.17	0	15
Methyl parathion	2.23	2.24	2.28	1	2
Parathion	2.66	2.80	3.00	5	7
Toxaphene	.93	1.02	1.26	10	24
Carbofuran	NA	NA	7.84	NA	NA
Average	--	--	--	4	10
Herbicides:					
Atrazine	2.53	2.47	2.32	-2	-6
Alachlor	3.71	3.93	4.04	6	3
Trifluralin	6.15	6.30	7.00	2	11
2,4-D	1.87	1.94	2.93	4	51
Butylate	NA	NA	2.80	NA	NA
Average	--	--	--	3	7
Fungicides:					
Zineb	1.83	1.88	2.27	3	21
Captan	2.46	2.74	3.36	11	23
Average	--	--	--	10	22

NA = Not available. -- = Not applicable. 1/ Carbaryl, 80 percent wettable powder; malathion, 5 pounds per gallon; methyl parathion, 4 pounds per gallon; parathion, 4 pounds per gallon; toxaphene, 6 pounds per gallon; carbofuran, 10 percent granule; atrazine, 80 percent wettable powder; alachlor, 4 pounds per gallon; trifluralin, 4 pounds per gallon; 2,4-D, 4 pounds per gallon; butylate, 6.7 pounds per gallon; zineb, 75 percent wettable powder; and captan, 50 percent wettable powder. 2/ Prices are reported for May 15 each year.

Source: (20).

Costs

Although pesticides account for only 3 percent of farmers' total production expenditures, they account for between 2 and 15 percent of the total costs for most major field crops (table 9). The proportion is even greater for fruits and vegetables. Pesticide expenditures have declined as a share of total production costs since 1978 because of the relatively smaller price increases for pesticides.

Total per acre pesticide costs in 1980 for peanuts were nearly double those for cotton and many times more than for wheat (table 10).

There are substantial regional variations in pesticide costs for almost all crops (table 11). The higher cost of pest control has been a major factor in the tremendous shift in cotton production from the Southeast to the Southern Plains.

Long-term Outlook

Despite the upturn in 1981 pesticide sales, growth in U.S. sales will be much less in the eighties than it was in the seventies and sixties. Increasing use of IPM, the use of more complex pesticides, and a market saturation for major crop herbicides point to a leveling off in pesticide use. U.S. growth will be less rapid than in other areas of the world, particularly developing nations. Because of lower use rates in developing nations and the need for increased food production, pesticide use will continue to increase substantially in these areas. One estimate places world expenditures for crop protection chemicals at $11.1 billion in 1984 (17). This would be a 14-percent increase over 1980, or an annual increase of 3.5 percent (table 12).

The U.S. farm pesticide use growth rate for the eighties has been pegged at less than 1 percent a year (table 13). However, another forecast by a pesticide industry representative indicates it may be as much as 3 or 4 percent a year (17). The lower projections assume greater use of highly concentrated formulations, IPM, improved application techniques, and more Government restrictions. Total shipments by U.S. manufacturers are projected to increase at just over 1 percent a year for the 1978-90 period (compared to 4 percent a year in 1966-76), with herbicides accounting for a major share of this increase. Pesticide exports by U.S. firms are expected to increase much more rapidly than domestic pesticide use. Nonagricultural uses also are expected to increase faster than farm use.

Because of higher energy costs, more farmers will use reduced tillage and no-till practices. This will increase the demand for herbicides, as herbicides are required to kill existing vegetation prior to planting. In addition, as with conventional tillage, herbicides are usually required in the early growing stages. Reduced cultivation may also encourage increased insect and disease populations resulting in a need for chemicals to control these pests. However, such increases are not likely to offset pressures toward reduced pesticide use or at least a substantial decline in the growth rate because of the growing adoption of IPM programs and use of more complex pesticides applied at lower rates.

Table 8--Changes in pesticide prices compared to prices of all production items

Year	Pesticides	All production items	Annual change: Pesticides	Annual change: All production items
	---Index (1967=100)---		---Percent---	
1970	97	109	--	--
1971	100	113	3	4
1972	104	119	4	5
1973	106	140	3	18
1974	123	164	16	17
1975	172	181	40	10
1976	174	183	1	7
1977	154	203	-11	6
1978	145	214	-6	5
1979	148	247	2	15
1980	165	268	11	9
1970-80	--	--	70	146

-- = Not applicable.

Source: (20).

Table 9--Pesticide share of total production costs 1/

Crop	1978	1979	Projected 1980
		Percent	
Cotton	13.6	11.7	11.5
Corn	8.8	7.9	7.3
Sorghum	6.5	5.6	5.2
Wheat	2.9	2.4	2.3
Soybeans	12.6	11.4	10.9
Peanuts	17.0	15.7	14.7
Rice	7.5	7.1	6.5

1/ Exclusive of land.

Source: (22).

Table 10--Pesticide costs per acre

Crop	1979	1980 (est.)	1985 (projected)
		Dollars	
Wheat	2.08	2.47	3.92
Corn	13.26	15.76	25.00
Sorghum	6.24	7.62	12.09
Soybeans	13.09	15.08	23.92
Cotton	34.86	42.42	67.28
Peanuts	66.84	77.00	122.13
Rice	21.54	25.16	39.91
Annual percentage change for all crops 1980-1985	--	--	12

-- Not applicable.
Source: (22).

Table 11--Regional variations in pesticide costs, 1979

Crop	Low		High		Average cost per acre, all regions
	Cost per acre	Region	Cost per acre	Region	
	Dollars	Name	Dollars	Name	Dollars
Cotton	10.99	Southern Plains	90.15	Southeast	35.87
Corn	9.05	Northern Plains	21.24	Southwest	13.67
Sorghum	6.67	Central and Southern Plains	9.16	Southwest	6.71
Wheat	.81	Central Plains	7.12	Southwest	2.16
Soybeans	6.28	Northern Plains	16.24	Southeast	13.09
Peanuts	30.67	Southern Plains	83.86	Southeast	66.84
Rice	19.86	California	26.06	Mississippi Delta	22.10

Source: (22).

NONMARKET PEST CONTROL DEVELOPMENTS

A number of nonmarket factors affect pesticide availability and costs. A major area to consider is the impact of pesticide regulations. There are also a number of non-chemical pest control techniques available. Some of these alternatives are likely to be used more extensively.

Table 12--Recent and projected worldwide changes in pesticide use

Item	Annual percentage change	
	1974-80	1980-84
	Percent	
Herbicides	9	3.3
Insecticides	5	3.5
Fungicides	6	4.3
Others	7	4.5
Total	7	3.5

Sources: (17, 24).

Table 13--Recent and projected U.S. changes in pesticide production and use

Item	Annual percentage change	
	1966-76	Projected 1978-90
	Percent	
Shipments:		
Herbicides	12	1.8
Insecticides	0	.4
Fungicides	0	1.1
Others	1	1.8
Total	4	1.2
Domestic use:		
Agricultural	5	.3
Nonagricultural	2	.8
Total	4	.4
Exports	5	3.0

Source: (12, 17).

Regulations

Pesticide application requirements, label specifications, and use restrictions affect farmers' pest control choices.

Rebuttable Presumption Against Registration Process (RPAR)

Legislation requires that pesticides which cause unreasonable adverse effects on the environment be removed from the marketplace. This activity is still probably the farmers' major regulatory concern. A major aspect of the reregistration process is the RPAR activity. There were about 45 chemicals, or groups of chemicals, involved in the RPAR process in 1980 (table 14). In addition, 6 pesticides had previously been canceled or suspended by the Environmental Protection Agency (EPA) and 15 pesticides had been voluntarily canceled by the registrants.

The RPAR process has two objectives: weigh risks of use of selected pesticides against benefits, and provide an informal process with greater public participation than had been allowed for pesticides decisions.

The result of the RPAR process is the development of regulatory options which could include: cancellation, reregistration, label modification, or restricted use. EPA may recommend cancellation where potential hazards are great and potential benefits are minimal. Affected parties may request administrative law hearings if they disagree with EPA's decision.

Table 14--Summary of EPA restrictive pesticide actions recently completed or currently in the review process, 1980

Action	Number
RPAR (PD 2/3) issued and intended action published 1/	7
RPAR (PD 2/3) issued still in review process 1/	16
Pre-RPAR review	14
Notice of cancellation and/or suspensions issued	3
Voluntary cancellations	5
Total	45

1/ A Position Document 2/3 (PD 2/3) completes the basic RPAR review process with the issuance of proposed regulatory options. After evaluation of comments on proposed options, a final decision (PD 4) is issued.

Source: (26).

The U.S. Department of Agriculture has estimated the combined annual added cost of pest control and lost production which would result from discontinuing the use of a number of products for which proposed regulatory actions were published. This estimate is $700 million. About $250 million of this was the result of higher control costs and $450 million was production losses (25). The products included: amitraz, DBCP, diallate, endrin, EDB, lindane, pronamide, and 2,4,5-T. EPA estimates that discontinuation of all fungicides currently being reviewed in the RPAR process could cost growers $5 billion to $6 billion for 1 year in lost production and added control costs (29).

EPA issued proposed regulatory options during the last year for diallate (30), lindane (31), EDB (33), and strychnine (34). Initial RPAR notices were issued for captan and carbon tetrachloride (26). Captan was cited for oncogenicity (tumor causing), mutagenicity (causing genetic alterations), and other chronic effects. Carbon tetrachloride was cited for oncogenicity and toxic effects on the liver and kidney. Use of perthane was canceled and 1081 was returned to the EPA registration process.

Diallate: The EPA proposal stated the intent that all emulsifiable concentrate formulations of diallate would be canceled 2 years after the RPAR decision published in the Federal Register, June 9, 1980. Granular formulations would be continued and registrants could apply for amended registrations to convert from emulsifiable concentrate formulations or to expand granular registrations to include crops on which emulsifiable concentrate formulations are currently used.

Lindane: The following uses of lindane were proposed for cancellation: (1) seed treatment, avocados, ornamentals (homeowner use), cucurbits, Christmas trees, pecans, forestry, structures, flea collars, dog dusts and shampoo, and household and minor uses; (2) use on hardwood logs and lumber with a 2-year phaseout period (during which, to avoid cancellation, the registrants must include warning labels concerning protective clothing requirements, and treatment would be made only by certified applicators); (3) use on pineapples unless labels are modified to include certain warnings concerning care in handling; and (4) commercial ornamental use and use on livestock unless labels are modified to include certain warnings. Application would be limited to certified applicators and protective clothing and equipment would be required. Registrations for dog washes would be continued with certain amended terms and conditions. Lindane dog wash products would be classified for restricted use and limited to applications by veterinarians only. Applicator certification would be required.

EDB: EPA proposed cancellation of certain uses of ethylene dibromide (EDB), changes in registration requirements for others, and phaseout of other uses by July 1, 1983. EPA cited risks of oncogenicity, mutagenicity, and reproductive disorders. About 13 to 15 million pounds are used annually. Fumigant uses on stored grain, grain milling machinery, and felled logs would be canceled. Quarantine use of EDB for fumigating citrus, tropical fruits, and vegetables would be canceled July 1, 1983. EDB uses for soil fumigation, fumigation of beehives, vault fumigation, and Japanese beetle control would be permitted only if certain terms and conditions of registration are amended. Soil fumigant uses would be continued, as residues have not been detected in crops grown on treated soil. However, food residue studies would be required to confirm these findings. Also, manufacturers would be required to determine the possibility of soil fumigant uses contaminating water supplies. EDB would be continued for termite control, but would have to be applied by commercial applicators.

Registration Standards--Pesticide Reregistration Process

EPA is implementing an activity--the Registration Standards Program--to reassess and reregister existing pesticides. 2/ The reassessment involves thorough review of the entire scientific data base underlying pesticide registrations and an identification of essential but missing scientific studies which may not have been required when the product was initially registered. Through the standards process, EPA plans to make broad regulatory decisions at one time for a group of pesticide products containing the same active ingredient rather than on a product-by-product basis. An estimated 600 standards are planned in the next 10 years or so, representing most of the 35,000 currently registered pesticide products.

Each standard will explain EPA's regulatory position on the use of that active ingredient in all pesticide products containing that chemical. The standard will include an analysis of the data on which the regulatory position is based, describe the rationale for the regulatory position, and state the conditions that must be met for continued pesticide product registration (26). If data analysis shows an RPAR criteria has been met, then some or all uses of the chemical will be diverted from the standard development until the RPAR process is completed. Results of the RPAR process will be ultimately incorporated into the standard.

The registration standards were distributed in 1980 when EPA sent reregistration guidance packages to the registrants of several pesticides. Registrants were requested to file a response concerning the required generic data within 90 days of receiving the package by notifying their intent to file the required data or by requesting exemption or voluntary cancellation. Other requirements to be met in 6 months concern labeling, data compensation (payments to be made by subsequent users to firms initially submitting data needed for registration), applications for amended registration, confidentiality, data reports, and a progress report on mid-term and long-term data development. Mid-term data would be required within 24 months and long-term data within 42 months.

Restricted Use Pesticides

Restricted use pesticides may be applied only by certified applicators. The list of restricted use pesticides is growing; it is essential that farmers intending to use such products obtain their certification as soon as possible. In a list published in February 1980, 45 pesticides were included in the restricted use category (28). All of the newly registered synthetic pyrethroids were included in the list.

2/ Mandated by 1972 Amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Major amendments to FIFRA in 1980 included congressional veto powers over implementation of EPA regulations affecting pesticides, and formal procedures for "peer review" to provide independent scientific evaluation of studies used as a basis for regulatory actions.

Production Practices

Effective and efficient pest control requires careful management and usually involves use of cultural as well as chemical pest control practices.

There are a number of important insect control factors to consider: identifying the problem, determining the economic threshold (that level of infestation at which losses if uncontrolled will exceed the cost of control), selection of the most appropriate alternative to reduce the population to some acceptable level, and proper timing of effective treatment. Scouts can help determine when an insect infestation is reaching the economic threshold level. Benefits of not applying insecticides until needed include delay in onset of insect resistance, reduction in undesirable residues, minimal damage to beneficial insects, and lower cost.

Integrated Pest Management

IPM incorporates good management practices with judicious use of chemicals, often achieving better pest control with fewer pesticides and at a lower cost than conventional pest control operations. IPM utilizes all suitable control methods and disciplines to keep pest populations below economically injurious levels. About 15 to 16 million acres are involved in IPM programs (15). This represents only 4 percent of the U.S. cropland (exclusive of pasture and rangeland); a Cooperative Extension Service plan outlines a program that would involve about half the U.S. crop acreage and livestock within 8 years (15). IPM tends to work best on stable crop systems, such as orchards and certain field crops such as cotton. For many other crops, IPM is presently limited largely to monitoring for proper timing of applications.

Scouting to detect pests to determine the optimum spraying times is the cornerstone of a good IPM program. Costs are usually nominal at about $2 to $5 per acre per year, but some crops require more scouting and costs may be higher.

Good management can be very effective in controlling a variety of pests. Pink bollworm, a major pest in the western cotton-growing areas, is a good example (1). Certain practices and procedures are important in pink bollworm control: plant during short period when conditions are optimum (do not plant too early); prevent early season damage by other insects; and produce the crop in shortest time possible by good fertilization, cultivation, and irrigation. Apply defoliants as soon as possible to avoid late boll development. Harvest as soon as possible and shred stocks immediately. Plow crop residues under as promptly and deeply as possible. This procedure prevents late season buildup of pink bollworm which greatly reduces the next season's population (1).

No-Tillage

With proper management, no-tillage achieves yields comparable to conventional tillage. This practice offers a number of advantages: reduced need for mechanical cultivation, and substantial energy savings, less erosion, greater moisture retention, and less weed germination. Corn planted by conventional methods had five times more weeds in the row area than no-till corn planted with a Buffalo till-planter (13). Still, no-tillage requires greater use of chemicals than conventional tillage. A foliar contact herbicide is essential to kill existing vegetation and herbicides are used as in conventional tillage to kill any subsequent germinating vegetation. Accurate and uniform application of the correct herbicides to a target weed population is essential in no-tillage production. Because of surface debris, insects and diseases may also be more of a problem than with conventional tillage.

Rotating corn land from a reduced or no-tillage program to a conventional tillage program periodically can be very beneficial. Moldboard plowing every 3 to 5 years helps mix the soil, checks perennial weed growth, and buries large numbers of weed seeds that tend to build up on the surface with no-tillage and reduced tillage practices (6).

Crop Rotations

Crop rotations can have a significant impact on insect, weed, and disease control. Until the development of cheap, effective organic insecticides, crop rotation was one of the primary practices used for insect control. However, since the early fifties, with the aid of chemicals, monoculture has become the dominant practice for some crops.

Corn rootworm thrives in continuous corn unless it is chemically controlled. A 1977 Iowa survey showed that 91 percent of the corn following corn was treated with soil insecticides, while only 25 percent of the corn was treated where soybeans had been grown the previous year (4). Some insects also tend to become resistant to certain chemicals after repeated use. For example, the corn rootworm in much of the Corn Belt was developing resistance to aldrin even before its cancellation in the mid-seventies. Crop rotations can also help reduce bollworm problems in cotton, grape colaspis in rice, and many other insect and disease problems. When rotations are used, crops should not be followed by similar crops, such as legumes following legumes or grains following grains.

Benefits of crop rotation for weed control depend on the crop and region. For example, johnsongrass, a serious problem in much of the South, can be controlled quite well in soybeans, but not nearly so well in corn, peanuts, cotton, or tobacco (5). Alternating between these crops can greatly improve control. The main reason for crop rotation today is not to directly control the weeds, but to allow the use of herbicides and other technologies that will.

Rotations can be a very important component of disease control. Crop rotation appears to be especially valuable in controlling root diseases, many of which cannot be economically reduced by fungicide treatments. Complete eradication of a pathogen cannot be obtained by rotation, but populations can usually be reduced to levels low enough to obtain profitable crops. Crop rotation is also one of the oldest and most important approaches to controlling nematodes that feed on the roots of annual crops.

Narrow Row Spacing

Trends toward narrow row spacing and the increase in broadcast seeding for soybeans means that fewer farmers have the option of using mechanical control after planting time. This increases reliance on herbicides.

Weeds such as johnsongrass, red rice, and morning-glory have become a problem in certain areas. Some researchers indicate these problems can be overcome to some extent by using "stale seedbed planting" (9). The soil is tilled and a preplant herbicide is incorporated 4 or 5 weeks before the beans are planted.

Annual grass weed control with postemergence herbicides has been one of the major limiting factors in soybean production, particularly in drilled or narrow row plantings. There are some promising new herbicides that should be available in a few years (registration permitting) that should offer excellent postemergence control of large grassy weeds and perennial johnsongrass.

Narrow rows or broadcast seeding also help in weed control by establishing a canopy sooner than with wide row spacing. Serious weed problems seldom develop once a canopy is established. Nebraska soybeans planted in 10-inch rows formed a canopy in 36 days, compared to 67 days for rows spaced 40 inches apart (5).

In 1980, about 15 percent of the soybeans were seeded in row widths of less than 10 inches or were broadcast (table 15). Ohio had the biggest share of acreage with narrow rows or broadcast seeding in 1980 (table 16). The Delta States followed Ohio in the use of narrow row or broadcast soybean plantings. The Delta States also had the largest proportion of soybean acreage with wide spacing. Wide row spacing is probably common in the Delta because many growers use cotton planting equipment, which generally plants in 38- to 40-inch row widths. Narrow row and broadcast seedings in the Delta are largely confined to areas where cotton is not produced.

Application

Worn or improperly calibrated spray equipment or the wrong equipment and improper mixing can result in serious overapplication or underapplication (19). About two-thirds of the applicators in 1979 were not within 10 percent of the recommended rate, while only 32 percent of the farmers were within this range (19). The average underapplication was 30 percent short of the recommended rate. The average over-application was 35 percent. Proper calibration can save as much as \$2 to \$12 an acre in added chemical costs and potential crop damage. Worn or improperly adjusted nozzles were the most frequent cause of improper application rates. Less than 1 percent of the funds spent for pesticide research was for developing and testing application equipment.

Alternative Controls

Production and management practices can help improve pest control and reduce the need for pesticides. A number of alternative control methods have been used successfully.

Biological

Biological control relies on natural enemies of the pest. The earliest U.S. example of successful control through introduction of natural enemies was when a lady beetle and a fly were imported from Australia in 1888 to control cottony cushion scale on citrus in California (18). These two predators eliminated the scale as an economic pest with a year. Most of the biological control agents have evolved over centuries

Table 15--Average row spacing for soybeans

Average row spacing	1976	1978	1980
		Percent	
34.6 inches and greater	60	51	40
28.5 inches and less	10	13	24
10.0 inches and less	NA	7	15

NA = Not available.

Source: (23).

Table 16--Average row spacing for soybeans, 1980

State	Narrow--10 inches and less	State	34.6 inches and greater
	Percent		Percent
Ohio	32	Louisiana	60
Louisiana	27	Tennessee	56
Mississippi	25	Mississippi	50
Arkansas	21	Arkansas	50
Tennessee	17	Iowa	48
Missouri	13	Illinois	36
Minnesota	12	Minnesota	35
Indiana	9	Missouri	34
Illinois	5	Indiana	28
Iowa	3	Kentucky	27
Kentucky	3	Ohio	14

Source: (23).

within natural ecosystems; therefore, they are quite specific and less likely to produce undesirable side effects than conventional pesticides. Biological pest control agents include viruses, bacteria, fungi, protozoa, nematodes, snails, arthropods, vertebrates, and higher plants. Effective use of biocontrol agents includes: the search for natural enemies and their introduction into the infested area, conservation to achieve the maximum use of natural enemies in an ecosystem, and augmentation which usually involves mass production and periodic distribution of biological control organisms (18).

Biological control of crop pests can be competitive with or more profitable than chemical control or other alternative control measures. However, little research has been conducted in an agricultural framework to compare biological and chemical pest control alternatives (16).

Diapause Weevil Control

Diapause control of weevils is a good cultural practice to minimize overwintering weevil populations (7). Heavily infested areas and areas providing late fall food supplies (small unharvested bolls, for example) are treated with insecticides in the fall to reduce the number of weevils going into diapause for overwinter survival. As much debris as possible is also removed to limit potential weevil food sources. This will reduce overall weevil population the following year, delaying the start of the weevil spray program and permitting beneficial insect populations to build (7).

Growth Hormones

Diflubenzuron, a recently developed growth hormone for control of the cotton boll weevil, continues to show good results. Diflubenzuron prevents the development of chitin, a material essential in shell hardening in the developing weevil embryo. Consequently, the embryo dies before or during the hatching period (8). Although cotton bolls are punctured when the adult lays its eggs, the boll matures normally when the embryos fail to hatch. Yields are increased as a result. In addition, since diflubenzuron does not harm beneficial insects and predators, bollworm spraying can be delayed with savings in worm control. Some growers in 1979 reported yield increases of 50 percent as a result of using diflubenzuron for early weevil control. Weevils usually pose no serious problem later in the season, once worm control begins (8).

REFERENCES

1. California-Arizona Farm Press, "Cultural Methods Effective in Controlling Pink Bollworm," Farm Press Publications, Inc., Clarksdale, Miss., Oct. 25, 1980.

2. Chemical Week, "Pesticides: $6 Billion by 1990," McGraw Hill, Hightstown, N.J., May 7, 1980.

3. ____________, "Adequate Supply of Feedstocks in 1980's," McGraw Hill, Hightstown, N.J., 1980.

4. Crops and Soils Magazine, "Crop Rotation vs. Monoculture--Insect Control," American Society of Agronomy, Jan. 1980.

5. ______________________, "Crop Rotation vs. Monoculture--Weed Control," American Society of Agronomy, Feb. 1980.

6. ______________________, "Rotate Tillage Instead of Crops," American Society of Agronomy, Oct. 1980.

7. Delta Farm Press, "Control Diapausing Boll Weevils in Cotton," Delta Farm Press Inc., Clarksdale, Miss., Sept. 19, 1980.

8. _______________, "Dimilin Results Called Impressive," Delta Farm Press Inc., Clarksdale, Miss., Aug. 20, 1980.

9. _______________, "Stale Seedbed Approach Being Evaluated," Delta Farm Press Inc., Clarksdale, Miss., Sept. 5, 1980.

10. _______________, "Crickets Problem in Louisiana Soybeans," Delta Farm Press Inc., Clarksdale, Miss., Oct. 17, 1980.

11. Eichers, Theodore R. "The Farm Pesticide Industry," U.S. Dept. Agr., Econ. Stat. Coop. Serv., AER-461, Sept. 1980.

12. ____________________, "Farmers' Use of Pesticides in 1976," U.S. Dept. Agr., Econ. Stat. Coop. Serv., AER-418, Dec. 1978.

13. Farm Chemicals, "How To Cash In On Minimum Till/No Till," Meister Publishing Co., Willoughby, Ohio, June 1980.

14. _____________, "The Battle over Drift," Meister Publishing Co., Willoughby, Ohio, July 1980.

15. Good, J.M., "Is Integrated Pest Management Succeeding?" U.S. Dept. Agr., Sci. Educ. Adm., paper presented, Entomological Society of American, Hershey, Penn., Sept. 26-28, 1979.

16. Papauizas, G. (editor), "Biological Control in Crop Production," U.S. Dept. Agr., Sci. Educ. Adm., (in press).

17. Predi-Briefs, "Pesticides," Predicasts Inc., Cleveland, Ohio, May, July, and Aug. 1980.

18. Ridgeway, Richard L., "Biological Pest Control," Yearbook of Science and the Future, Encyclopedia Britannica, Inc., 1981 edition.

19. Successful Farming, "The Billion Dollar Blunder," Meredith Corp., Des Moines, Iowa, Apr. 1980.

20. U.S. Department of Agriculture, Agricultural Prices, Econ. Stat. Coop. Serv., Pr 1 (5-80), May 30, 1980, and earlier issues.

21. ______________________________, Farm Production Expenditures, Econ. Stat. Coop. Serv., SpSy 5 (9-80), Sept. 1980 and earlier issues.

22. ______________________________, "Costs of Producing Selected Crops in the United States--1978, 1979, and Projections for 1980," Econ. Stat. Coop. Serv., prepared for Comm. on Agr. and For., U.S. Senate, July 1980, revised data.

23. ______________________________, Crop Production, Acreage, Yield, Production, CrPr (80), Nov. 1980.

24. ______________________________, "The Pesticide Review," Agr. Stab. Cons. Serv., Dec. 1978 and earlier issues.

25. ______________________________, "Economics of Pesticide Regulation," Econ. Stat. Coop. Serv., unpublished data, Apr. 2, 1980.

26. U.S. Environmental Protection Agency, "October 1980 Status Report on Rebuttable Presumption Against Registration (RPAR) and Registration Standards," Office of Pesticides and Toxic Substances, Oct. 1980.

27. ______________________________, "Pesticide Industry Sales and Usage, 1980 Market Estimates," Office of Pesticides and Toxic Substances, Sept. 1980.

28. ______________________, "Federally Registered Restricted Products," Office of Pesticides and Toxic Substances, Feb. 1980.

29. ______________________, "Fungicides: An Overview of Their Significance to Agriculture and Their Pesticide Regulatory Implications," Office of Pesticides and Toxic Substances, Oct. 1980.

30. U.S. Federal Register, "Diallate; Preliminary Notice of Determination Concluding the Rebuttable Presumption Against Registration of Pesticide Products and Notice of Availability of Position Document," June 9, 1980.

31. ______________________, "Notice of Determination Concluding the Rebuttable Presumption Against Registration of Pesticide Products Containing Lindane; Availability of Position Document 2/3," July 3, 1980.

32. ______________________, "Petitions of Friends of the Earth for Rulemaking and Policy Changes; Aerial Application of Pesticides," Jan. 17, 1980.

33. ______________________, "Pesticide Products Containing Ethylene Dibromide (EDB) Preliminary Notice of Determination Concluding the Rebuttable Presumption Against Registration, Notice of Availability of Position Document 2/3," Dec. 10, 1980.

34. ______________________, "Strychnine; Preliminary Notice of Determination Concluding the Rebutabble Presumption Against Registration of Pesticide Products; Notice of Availability of Position Document 2/3," Nov. 5, 1980.

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